4. Express in terms of power, P_r, received by an antenna with unity gain (0dB) and wavelength, $\lambda = \frac{c}{f}$.

$$\text{Effective Area} = \eta \, A_R = 1 \cdot (\frac{\lambda^2}{4\pi})$$

$$P_r = W \cdot \eta \, A_R = W \frac{\lambda^2}{4\pi} = \frac{(\frac{E \lambda}{\pi})^2}{480}$$

$$W = P_r \cdot \frac{4\pi}{\lambda^2}; \; E = \frac{\pi}{\lambda} \sqrt{480 \, P_r} = \frac{\pi \, f}{c} \sqrt{480 \, P_r}$$

Example:

$$-20 \, dBu = -20 - 145.76 = -165.76 \, dbw/M^2$$

i.e., W = E - 145.76 (dBw/M^2

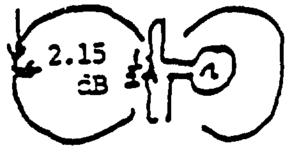
or E = W + 145.76 (dBu)

Some Examples With Microvolts/Meter

An FM radio is assumed to give a good quality signal at 37 dB (μV/Meter) at 150 MHz. A good signal (about 30 dB S/N) corresponds to about 12 dB C/N + a 28 dB fade margin. The radio bandwidth is 17 KHz. The radio frequency is 150 MHz. What is the noise figure of the receiver?

Convention is mobile radio measures gains of antennas relative to 1/2 wave dipoles.

$$G\tfrac{1}{2}\lambda \text{ Dipole} = 2.15 \text{ dB}$$



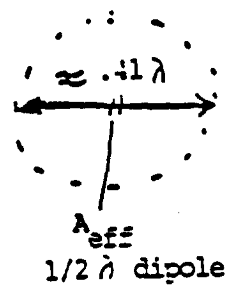
The effective area of a $\frac{1}{2}\lambda$ dipole is:

$$\eta A = \frac{G\lambda^2}{4\pi}$$

$$@\ 150 \text{ MHz};\ \lambda = \frac{3\times10^8}{150\times10^6} = 2\text{M}$$

$$\eta A = \frac{10^{.215}\times4}{4\pi} = 0.52M^2$$

$$\text{Deff} = \sqrt{4\eta A/\pi} = 0.83\text{M}$$



Note that the effective area of a halfwave dipole (an antenna with 2.15 dB gain) increases as λ^2. The physical dipole length increases as λ; but the capture area increases as λ^2.

The flux density is specified in terms of dB(μV/M)

The term dBu means dB above a microvolt. Note that dB for voltage is defined as 20 log (V_2/V_1). The power in watts/M^2 is given by:

$$\boxed{\text{W} = W_{1\mu v} + \text{dBu} = -145.76 + \text{dBu:}\ [\text{watts}/M^2]}$$

The radio power necessary is 37 dBu. The corresponds to a power flux density of:

$$\text{W} = 37 - 145.76 = -108.76 \text{ dBW}/M^2$$

The carrier power received with a $\frac{1}{2}\lambda$ dipole at 150 MHz with a 37 dBu signal is:

$$P_r = W \cdot \eta A = \text{-108.76 dBW}/M^2 + 10 \log_{10}(0.52) = \text{-108.76 - 2.8} = \text{-111.56 dBW}$$

$$\text{C/N} = 12 \text{ dB}; \ \text{B} = 17 \text{ kHz} \rightarrow 42.3 \text{ dBHz}; \ \text{k} = \text{-228.6}$$

$$\text{N} = P_r - \text{C/N} - \text{Fade Margin} = \text{k} + \text{T} + \text{B}$$

$$\text{T} = P_r - \text{C/N} - \text{F.M.} - \text{k} - \text{B} = \text{-111.56} - 12 - 28 + 228.6 - 42.3 = 34.74 = 2.976°\text{K}$$

Example :

How much power is needed to reach a range of 50 kM (32 Mi) if the FM receiver requires 37 dBu field strength 50 percent of mobiles 50 percent of the time? The transmitter is on a tower 150 m above average terrain and the transmit antenna has a gain of 8 dB.

From the CCIR chart (Figure 4) the signal strength for a transmitter with 1 kW e.r.p. is given as a function of range and transmitter tower height.

At 50 km for a 150 m tower the flux density is 35 dBu.

To achieve 37 dBu we need 2 dB more ERP. . . . We need to transmit 2 dB more than the 1 kw into the antenna:

Absolute ERP = 30 dBW + 2 dB

= 32 required

Actual Antenna Gain = 8 dB

Power Required = 32.0 - 8 dB = 24.0 dBW

P_T = 251 watts

Example:

How much power can be saved by buying a 300 M tower?

With 300 M tower at 50 kM the 1 kW E.r.p. gives 42.5 dBu:

To achieve 37 dBu we need 5.5 dB less power:

Absolute ERP = 30 dBW - 5.5 = 24.50 dBW

Power required = 24.50 - 8 = 16.50 dBW

$$P_T = 44.67 \text{ watts} \quad \text{(was 251 watts with 150 meter tower)}$$

Example:

With the ACSB instead of FM radios, how much can the above example (300 M tower) be extended in range with the same transmit power (44.67 watts)?

The ACSB radios require 28 dBu to achieve the same signal quality that FM achieves at 37 dBu.

The ACSB requires 37 - 28 = 9 dB less Flux Density. The chart reference level at 50 kM for a 300 M tower was 42.5 dB, the signal for ACSB can be 9 dB weaker. i.e., 33.5 dB on reference chart. This occurs at 75 kM

(Previous FM was 50 kM)

Example:

What would be the range for a 300meter tower transmitting 72 watts at 800 MHz (use other charts [Figure 9]). The transmit antenna has 8 dB gain (absolute).

The ERP (absolute) is:

$$ERP = 10\log_{10} 72 + 8 = 18.65 + 8 = 26.65 \text{ dBW}$$

The ERP of the reference example.

$$ERP_{ref} = 30 \text{ dBw}$$

For FM reception we require 37 dBu.

The actual transmitter has 30.0 - 26.65 = 3.35 dB less ERP than the reference chart transmitter.

Therefore, instead of 37dBu on the chart we need to find $37 + 3.35 = 40.35\ dBu$.

For the 300 tower 40.35 dBu occurs at 58 kM.

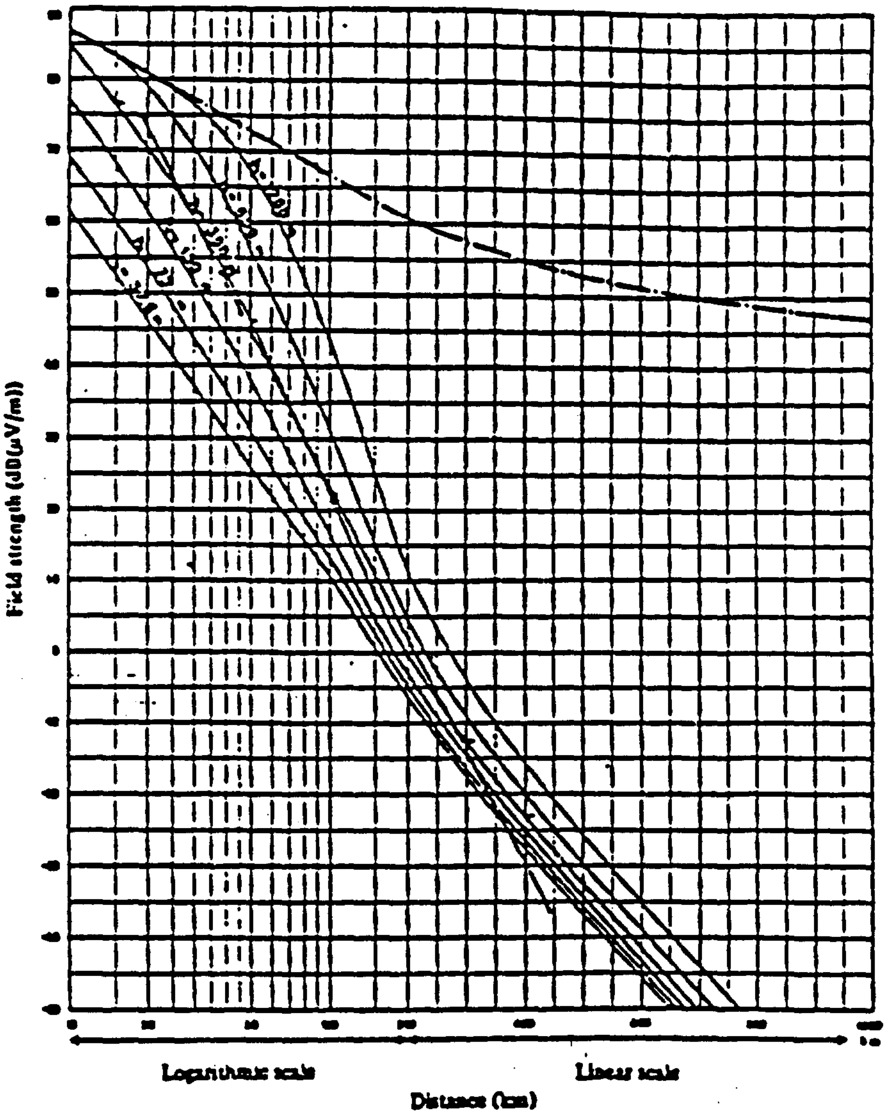


FIGURE 9 – *Field strength (dB(μV/m)) for 1 kW e.r.p.*

Frequency: 450 to 1000 MHz (Bands IV and V); Land: 50 % of the time;
50 % of the locations; h_2 = 10 m; Δh = 50 m

—·—·— Free space

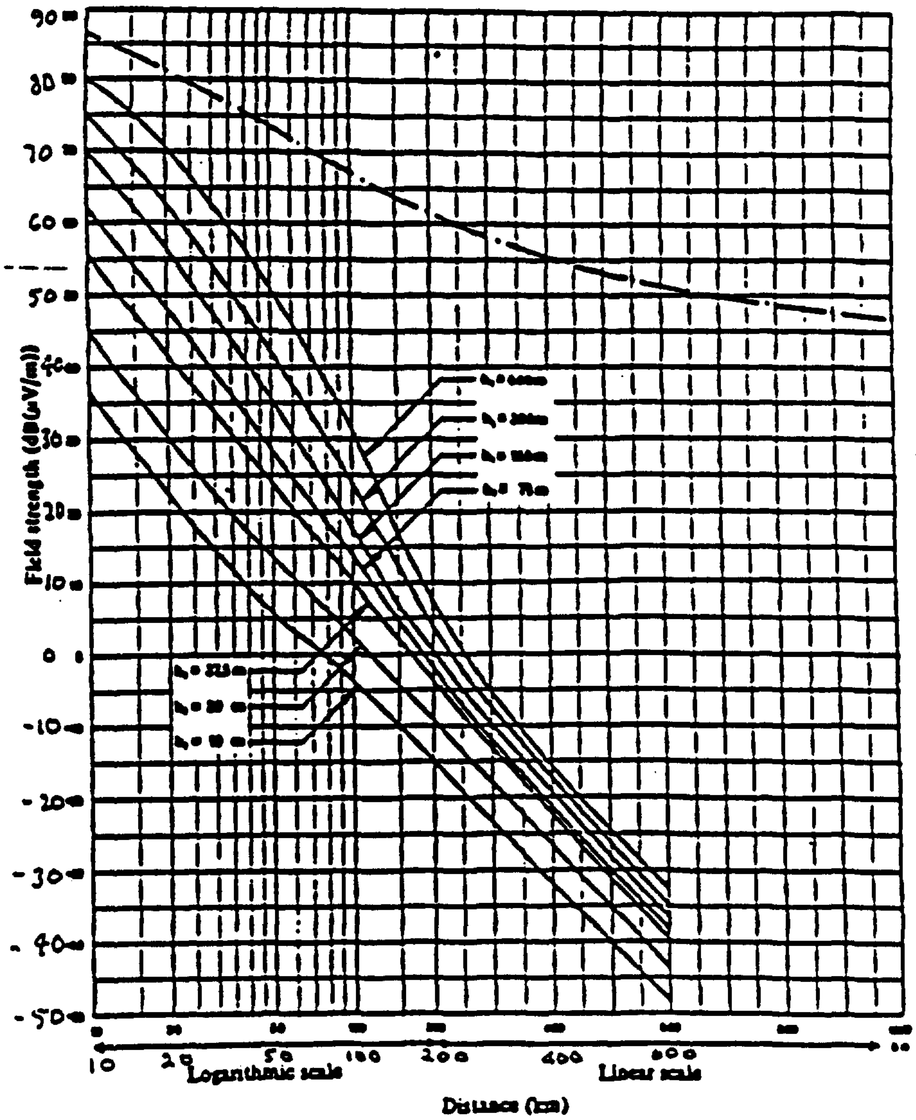


FIGURE 4 – Field strength (dB(μV/m)) for 1 kW e.r.p.

Frequency = 150 MHz, land, rural, 50 % of the time; 50 % of the locations; h_2 = 3 m

———·——· Free space

Note: The final chart shows field strength variation for very short distances. The chart is from the United States Federal Communications Commission which uses miles on horizontal axis and ERP on the vertical. ERP is given for radiation of one kilowatt.

E.R.P. from a 1/2–wave dipole. The scale is the same as that on the previous charts. One can be thought of as radiating 30 dBW into a 0 dB antenna. The other can be thought of as radiating 27.85 dBw from an antenna with 2.15 dB gain.

Let's check the curve given on this chart for the free space field strength.

The basic equation for free space flux density is:

$W = \frac{E.R.P.}{4\pi R^2}$; (R in Meters, W in Watts/M^2

On this chart E.R.P. = 30 dBW (1 kilowatt)

$$W = ERP - 10 log_{10} (4\pi R^2)$$

$$W = 30 - 10 log_{10} (4\pi R^2)$$

$$dBu = W + 145.76 = 30 + 145.76 - 10 log (4\pi R^2)$$

$$dBu = 175.76 - 10 \ log (4\pi R^2)$$

But range D is given in miles; R = D x 1,609; Meters

$$-10 \ log_{10} (4\pi R^2) = -10 \ log_{10}(4 \pi \times 1,609^2) - 10 \ log_{10} D^2$$

$$-10 \ log_{10} (4\pi R^2) = -75.12 - 20 \ log_{10} D$$

$$dBu = 175.76 - 75.12 - 20\,log_{10}\,D$$

$$\boxed{dBu = 100.64 - 20\,log_{10}\,D; \quad D = mi}$$

Free space field strength dBu at D miles.

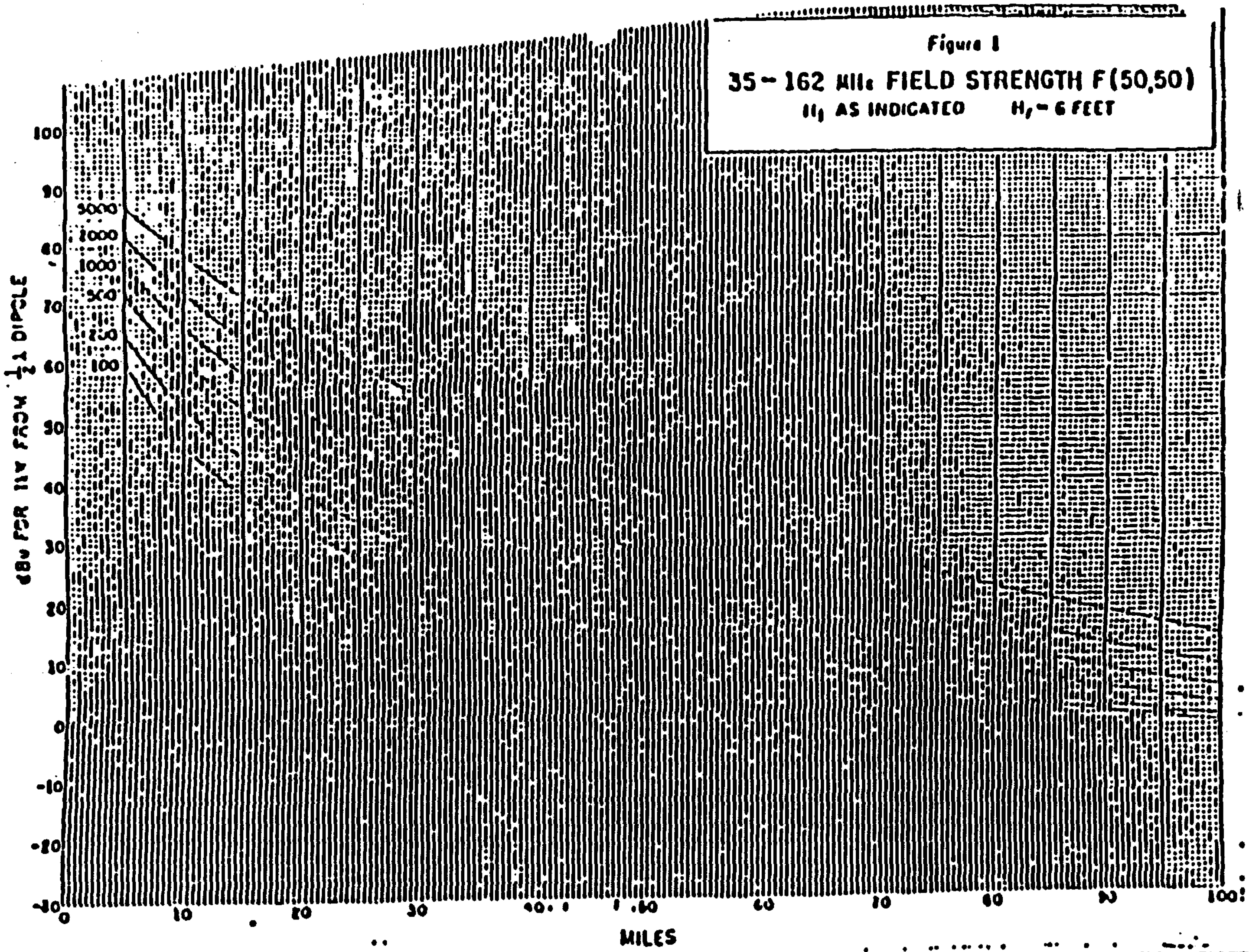


Figure 7. Field Strength Variation 5 mi to 100 miles

DATE: 12-23-82

SITE:

BY: BRUCE PAUL

Contemporary Communications Corporation

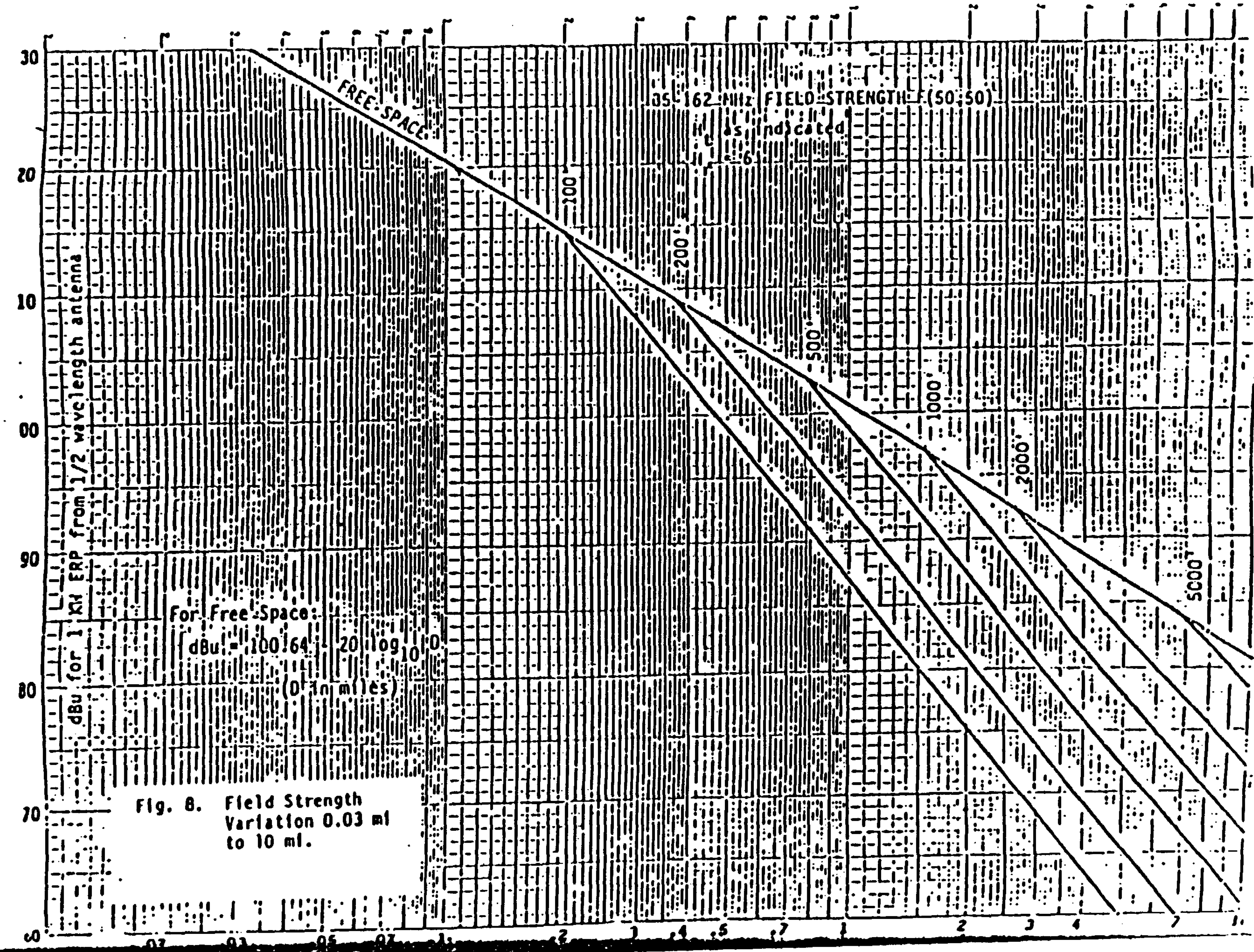


Fig. 8. Field Strength Variation 0.03 mi to 10 mi.

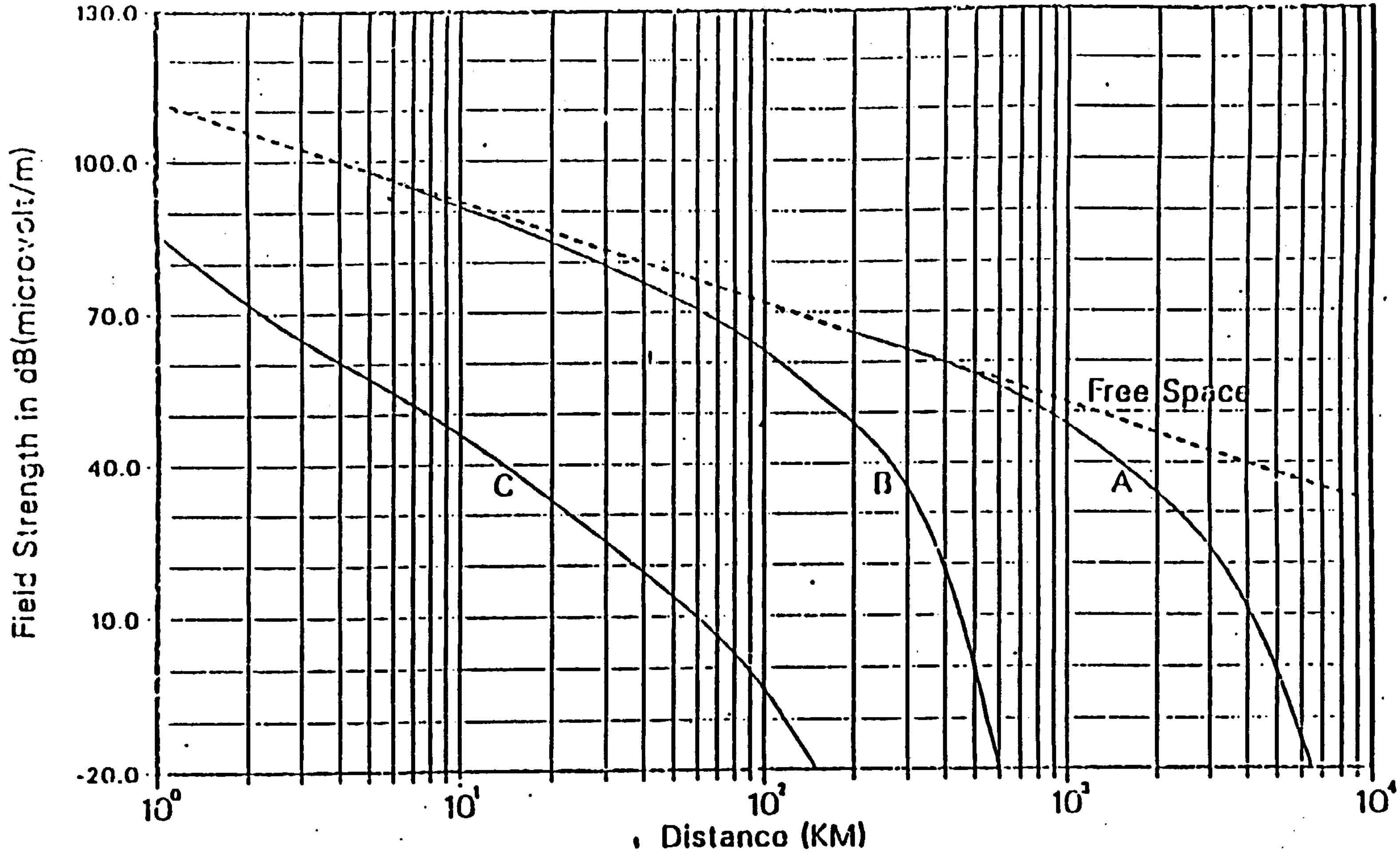


Figure 3-4: - GROUND WAVE VARIATION WITH DISTANCE, FREQUENCY AND GROUND TYPE
A: F=10KHz, sea and average land,
B: F=10MHz, sea (45 S/M),
C: F=10MHZ, average land (.003 S/M).

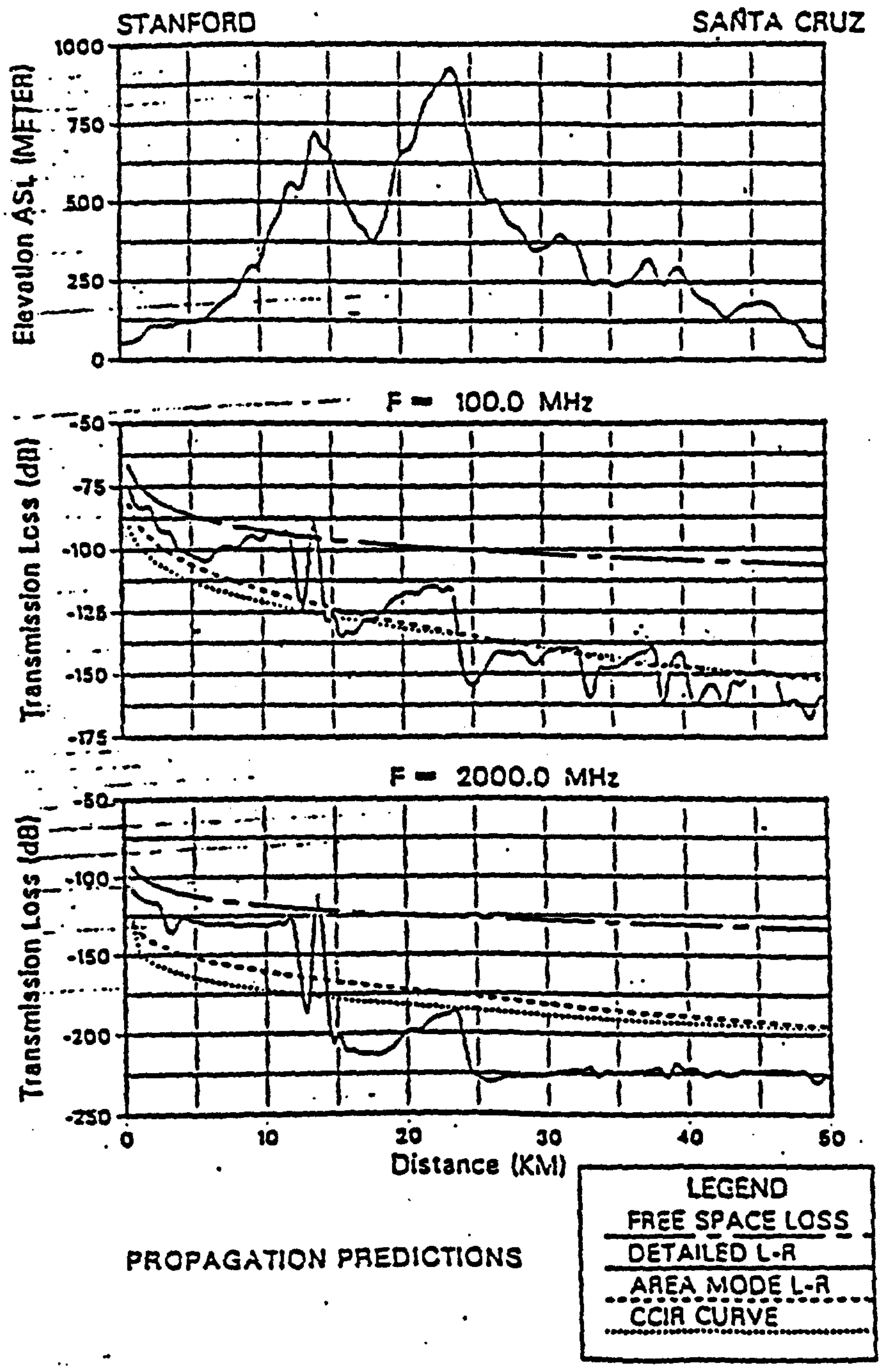


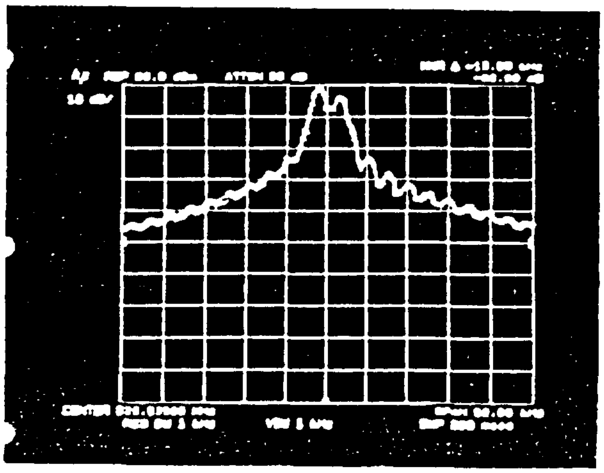
Figure 3-10: Propagation Loss Predictions Using the Longley-Rice Model and the CCIR Curves

MODULATION SPECTRUM IN THE REMOTE POCKET RADIO

DATE: MAY 21, 1991
AUTHOR: BEHRUZ REZVANI
REPORT #: 910521-35

The spectrum of the data packet radio is shown in Figure 1.

Before using filters



After using filters

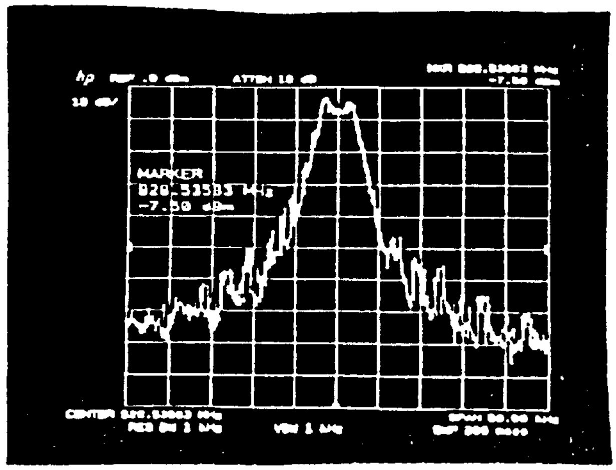


Figure 1: Spectrum of the transmitted signal by the remote unit

The spectrum was left wide in phase I for two reasons. First, the E.F. Johnson radio was not available in a narrow-band version with rapid delivery. Refinement of the User unit transmit spectrum requires simultaneous adjustment of the base station receiver filter. Second, the priorities were to make a demonstration of the system including custom software to illustrate power industry applications. This development took precedence over the spectrum refinement.

This report examines the causes and presents the right filtering for each of the three sources of the wide band output. These filters not only reduce the bandwidth of the modulation signals and, as a result, the bandwidth of the output signal, but should also maintain the distinction between "zeros" and "ones" in order to prevent increase of the bit error rate.

This spectrum of the signal is the result of two phenomenons, one is the FSK modulation of the data stream and the second is the result of the on/off remote unit transmitter. Figure 1 reveals the spectrum signal transmitted by the remote unit is out of the specification standards set by the FCC.

Table 1 compares the FCC specification standard with the signal transmitted by the remote unit.

TABLE 1

Off set Frequency [KHz]	FCC Standard [dB]	Signal Strength [dB]
0	0	0
1	0	0
2	17	12
3	34	20
3.125	36	21
3.7	43.	22
4	43	22
10	43	32
15	43	40
25	43	45

The data modulation in the remote packet radio is FSK with a 2.4 kbit rate. The maximum frequency for the data is 1.2KHz square wave. The data stream consists of the fundamental frequencies with the spectrum covering from 0 to 1.2KHz and odd harmonics. The amplitude of these harmonics are proportional to $1/n$ which n is the number of harmonics. Figure 2 reveals the spectrum of the data stream up to 25KHz. The spectrum shows that the amplitude of the signal at 4KHz offset frequency is 10dB and at 6KHz offset is 12dB. The modulated signal with this data will produce data at offset frequencies well beyond the allowed bandwidth.

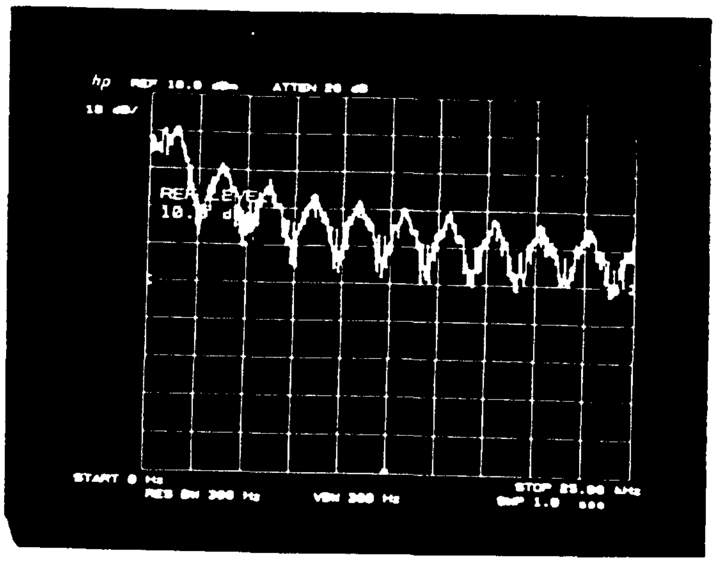


Figure 2: Spectrum of the example data

The second cause of the wide spectrum is the result of switching the transmitter on and off. The power of the transmitter should be off when not sending data. Therefore, it will not interfere with the other transmitters and with its own receiver. The switching time for power is reduced to less than .2msec, which is 1/2 of the bit time. This switching appears as amplitude modulation on top of the carrier. The switching occurs in two places in the transmitter circuit, one is in the power supply of the driver amplifier stage and the second in the power supply of the power amplifier stage. The spectrum of the voltage switching in the driver stage and power stage is illustrated in Figures 3 and 4.

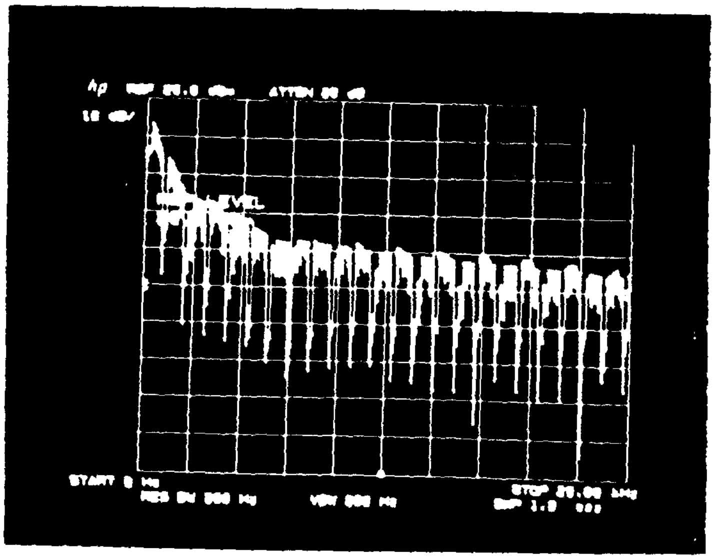


Figure 3: Spectrum of switching power supply, driver stage

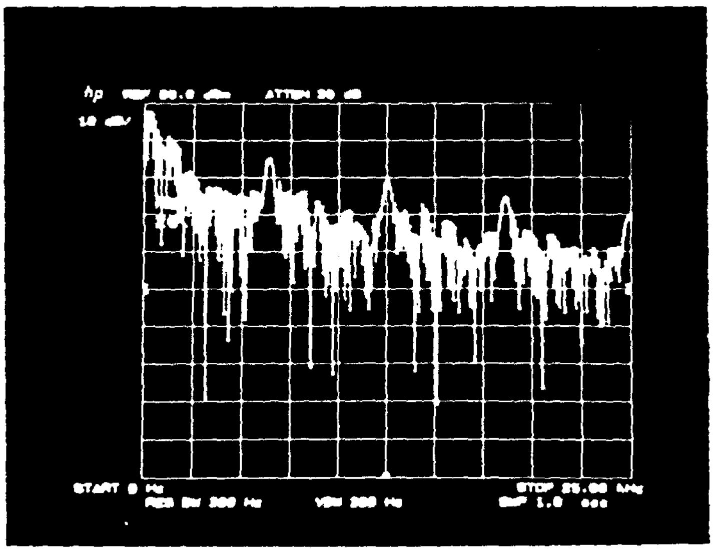


Figure 4: Spectrum of switching power supply, power stage

As shown in Figures 3 and 4, the spectrums of both signals are wide and as a result will contribute to the widening of the transmitted signal. The ratio of on/off time to the "one" of the data is 1:1 in single bit, and 1:64 on average for the data. Even with the assumption of 3 single bit transmission for each data transmission, the ratio of on/off switching time to that of data is 1:16. Thus, the spectrum contributed by the switching of the power supplies is 12dB. The figure below illustrates the result in the spectrum analyzer of the maximum hold position. For your reference, an example of the data stream is shown in Figure 5.

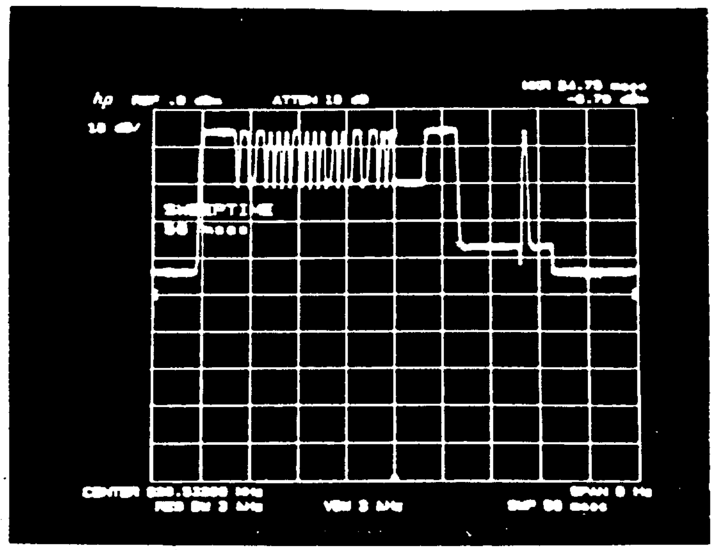


Figure 5: Data stream of remote unit transmitter

The improvement in the spectrum will reduce the bandwidth signal spectrum, and at the same time it will maintain the clarity of signal and power supply switching speed.

The data stream passes through a four-stage low pass maximally flat filter, with a 3dB bandwidth located at 2.4KHz. The spectrum of the signal shown in Figure 2 is reduced to the spectrum one shown in Figure 6.

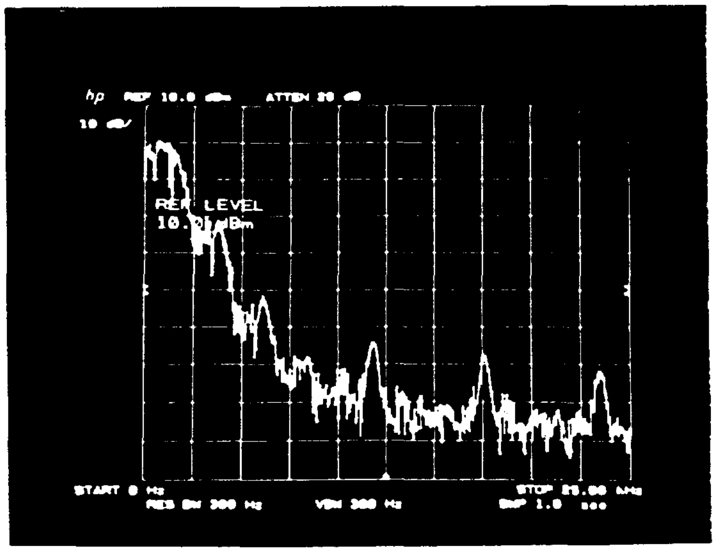


Figure 6: Spectrum of data stream after 4 stage low pass filtering

The schematic for filtering the power supply for the driver amplifier stage is shown in Figure 7.

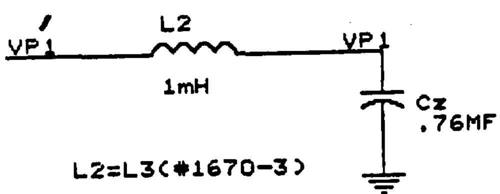


Figure 7: Schematic for the filter in the driver amplifier stage

The filter is the low pass Lc circuit with the 3dB bandwidth at 8KHz. Since the current consumption is 13ma in the driver stage, the inductor for this filter does not need to be low-resistance. The circuit consists of a switch with 50 Ω series resistance. The spectrum of the voltage after the filter is illustrated in Figure 8.

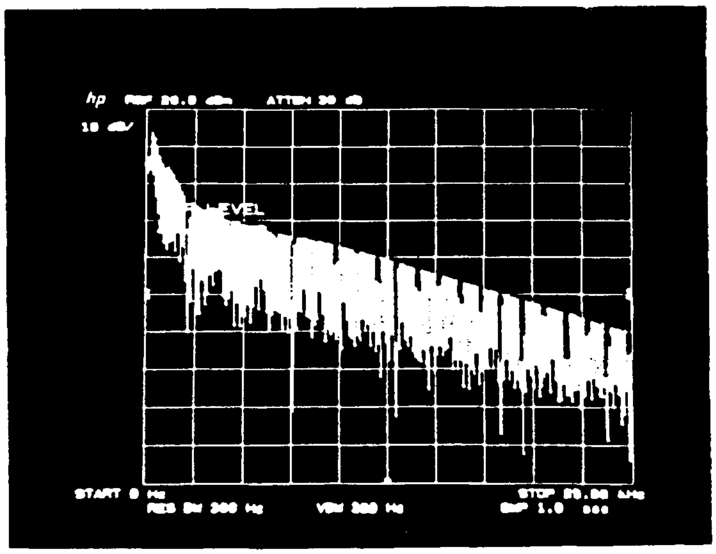


Figure 8: Output of filter for the first stage amplifier power supply

The schematic for the filter used in the power supply of the power amplifier stage is illustrated in Figure 9.

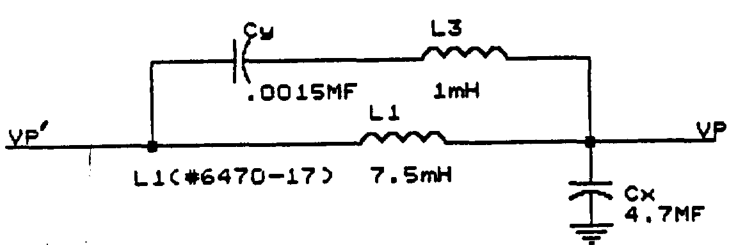


Figure 9: Schematic for the filter in the power supply for power amp

As shown in Figure 10, the filter consists of 3 basic filtering elements. The first part is a basic low pass filter of CX, and L. This low pass filter is designed with 1.2KHz, 3dB bandwidth. The filter is a 2 stage, therefore, it will attenuate the frequencies with a sharp slope. At 6KHz, there is a signal which has to be attenuated more. For this reason, capacitor Cy is provided. This capacitor, in conjunction with L_1, introduces a notch filter at 6KHz. As a result the attenuation is higher at this frequency. However, at higher frequencies this cap(Cy) disables the effect of inductor L_1, and the filter will pass high frequencies. In order to compensate for this effect, the inductor L_3 is used, so that at higher frequency the circuit is equivalent to the low pass filter parallel capacitor of CX and series inductor of L which is the equivalent of $L_1//L_3$. This low pass filter has the same slope as the original with a higher cut off frequency. The attenuation in this filter is about 10dB less than the one in the original filter. The output of the filter is shown in Figure 10.

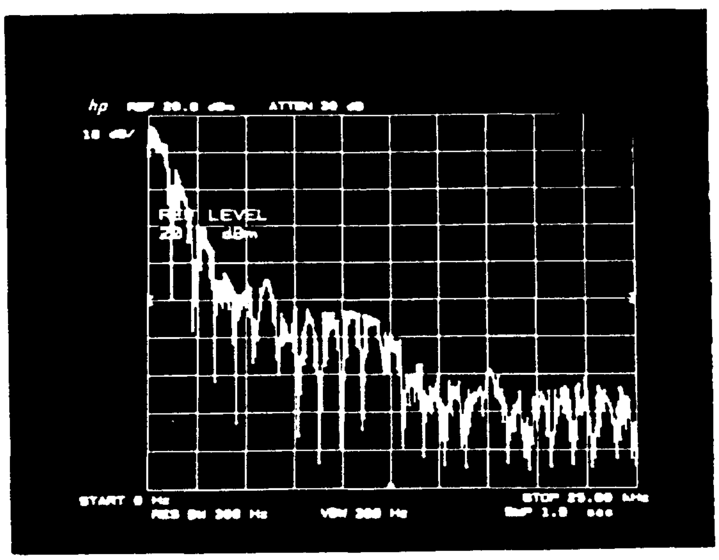


Figure 10: Output of filter in power supply for power amplifier

Since the current that is drawn from this power supply by power amps is 130mA, the inductor in the main series path (L_1) should be a low resistive one. The inductor chosen is #6470-17 which is 7.5MHy and the maximum DC resistor for this inductor is 11ohm. The actual resistance performed by this inductor is about 6 ohms, the voltage drop across the inductor is .8 volts. Inductance L_3 is not in the Dc path, therefore, it is not necessary for it to be a low resistance one.

Using the 3 filters mentioned in this report improve the response from Figure 1 to Figure 11.

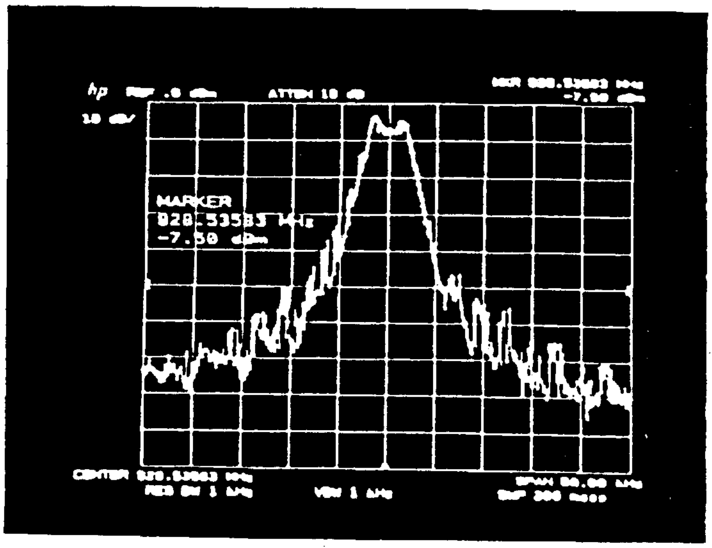


Figure 11: Spectrum transmitter signal from the remote unit using low pass filters in the data and power supply path

The comparison between FCC specification standards and signal transmitted by the remote unit with and without filters are shown in Table 2.

TALE 2

Off set Freq. [KHz]	FCC Standard [dB]	Signal Strength without filter	[dB] with	Improvement [dB]	Shortage vs	Comment
0	0	0	0	0	0	
1	0	0	0	0	0	
2	17	12	15	3	2	
3	34	20	25	5	9	
3.125	36	21	28	7	8	
3.7	43	22	40	18	3	
4	43	22	43	21	0	
10	43	32	70	38	0	
15	43	40	75	35	0	
25	43	46	80	34	0	

The spectrum shows that the bandwidth for 36dB attenuation is at 7KHz instead of 6.25KHz. The spectrum can be reduced to 6.25KHz by reducing the deviation of the modulated signal.

The zero one pattern for single bit is shown in Figure 12.

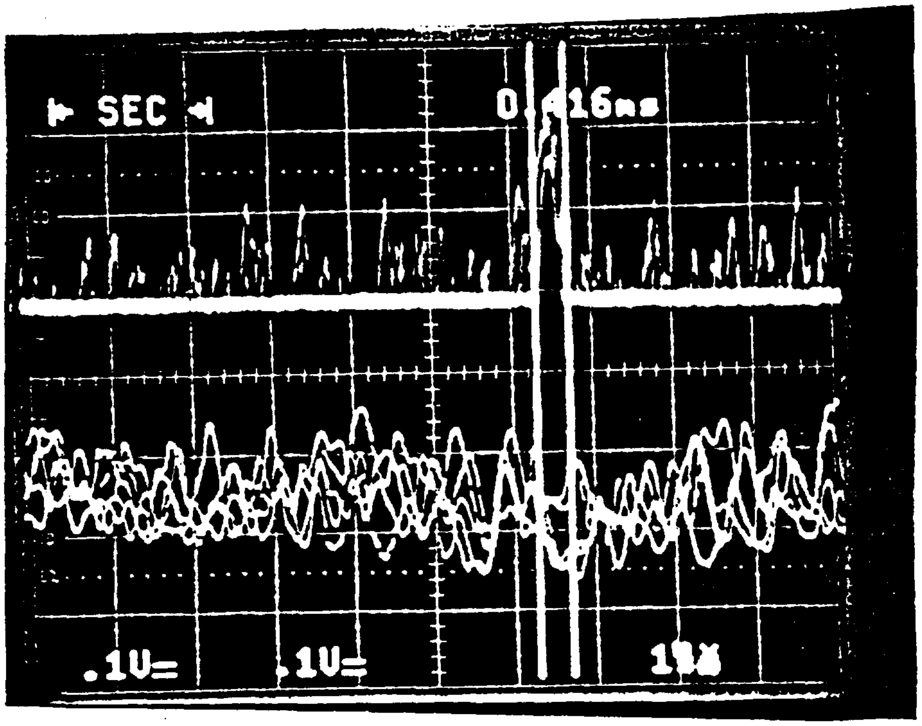


Figure 12: Carrier detector and data with eye diagram

The top portion of Figure 12 is the trace of carrier signal detected by the base station receiver. Illustrated at the cursor position is a clear carrier level that corresponds to "0" and "1" of the single bit with high S/N ratio. The bottom portion reading is the trace of data signal received by the base station. At the same cursor position, there is a clear open eye formed by the "0" and "1" level of the single bit. Both traces are at 100dB attenuation.

TTI - DAC Phase I Field Trials

Elevation Chart - Phase I Field Trials

Site Dist	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
0.0	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40
0.2	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40		40
0.4	40	40	90	100	40	40	40	40	40	50	60	50	50	50	50	60	40	40	40		40
0.6	60	80	250	140	40	40	40	60	40		100	70	70	70	50	100	50	40	60		
0.8	240	320	250	200	40	40	40	40	40			70	70	70	50	80	50	50	70		
1.0	160	280	220	300	40	40	40	200	120			120	120	120		80		50	80		
1.2	40	360	140	120	40	40	40	180	160			160	160	160		90			120		
1.4	40	80	180	160	40	40	40	60	200			100	100	100		90					
1.6	40	80	60	40	40	40	40	100	180			120	120	120							
1.8	40	40	100		40	40	40	180	200			80	80	80							
2.0	40	40	40		40	40		180				80	80	80							
2.2	70	40	40		40	40		150													
2.4	120	40	100			40		200													
2.6	560	40	50			40		20													
2.8	400	40	130			60		20													
3.0	260					200		60													
3.2	400					60		20													
3.4	680							20													
3.6	680							20													
3.8	760							20													
4.0	800							20													
4.2	880																				
4.4	1000																				
4.6	720																				
4.8	480																				
5.0	840																				
5.2	750																				

CONFIDENTIAL

Profile - Site 2

Site 2 - HandiCup Plant